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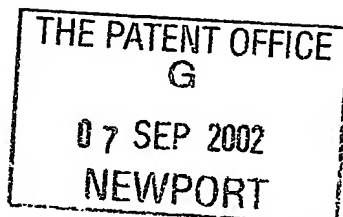
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1/77

10SEP02 E746680-3 D02004  
P01/7700 0.00-0220838.7

## Request for grant of a patent



The Patent Office

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1. Your reference	P31080/JED/JDB		
2. Patent Application Number (the Patent Office will fill in this part)	0220838.7		07 SEP 2002
3. Full name, address and postcode of the or of each applicant (underline all surnames)	Robert Gordon University Schoolhill Aberdeen AB10 1FR		
Patents ADP number (if you know it)	6310098 003		
If the applicant is a corporate body, give the country/state of its incorporation	United Kingdom		
4. Title of the invention	"Screen System"		
5. Name of your agent (if you have one)	Murgitroyd & Company		
"Address for service" in the United Kingdom to which all correspondence should be sent (including the postcode)	165 - 169 Scotland Street Glasgow G5 8PL		
Patents ADP number (if you know it)	1198015 ✓		
6. If you are declaring priority from one or more earlier patent applications, give the country and the date of filing of the or of each of these earlier applications and (if you know it) the or each application number	Country	Priority application number (if you know it)	Date of filing (day / month / year)
7. If this application is divided or otherwise derived from an earlier UK application, give the number and the filing date of the earlier application	Number of earlier application	Date of filing (day / month / year)	
8. Is a statement of inventorship and of right to grant a patent required in support of this request? (Answer 'Yes' if: a) any applicant named in part 3 is not an inventor, or b) there is an inventor who is not named as an applicant, or c) any named applicant is a corporate body. See note (d))	Yes		

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Description 14

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*MURGITROYD*  
MURGITROYD & COMPANY

Date 06/09/2002

12. Name and daytime telephone number of  
person to contact in the United Kingdom

James D Brown 01224 706616

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1     "Screen System"

2

3     This invention relates to a screen and in particular  
4     a screen for use in oil and gas wells.

5

6     More than 80% of oil and gas clastic reservoirs  
7     world-wide are known to be in various stages of  
8     unconsolidation which may potentially cause the  
9     reservoir to produce sand. This is especially true  
10    for reservoirs located in deep waters. Similarly,  
11    many of the reservoirs in mature fields are in an  
12    advanced state of depressurisation, which makes them  
13    susceptible to sand failure. Consequently, at  
14    various stages in the economic life of a field, a  
15    reservoir located therein will generally require  
16    some form of sand control completion. To this end,  
17    there is currently an increasing trend towards the  
18    use of different screen systems (either barefoot in  
19    openhole completions or gravelpack screens) in the  
20    completion of wells drilled through reservoirs with  
21    sanding problems.

22

---

1 In an attempt to improve oil or gas recovery at  
2 minimal cost from marginal and mature fields,  
3 horizontal, extended reach and multilateral wells  
4 are becoming the most popular advanced wells for  
5 optimal field developments, especially in  
6 challenging deep water High Pressure/High  
7 Temperature (HP/HT) environments like the Atlantic  
8 margin. Sand control in these wells with screen  
9 systems (with or without gravelpack), involves  
10 placing the selected screen in the well bore within  
11 a pay region specifically designed to allow  
12 reservoir fluids to flow through the screen slots  
13 whilst enabling the screen to filter out formation  
14 sand grains. A key part of the screen design  
15 therefore is the screen slot gauge, wherein this  
16 parameter is estimated by way of the formation grain  
17 size distribution. However, any solids loading or  
18 sand migration through the slots may lead to  
19 plugging and screen erosion with attendant downhole  
20 problems including sand production.

21  
22 A variety of different generic screen systems are  
23 currently in use in the oil industry, such as simple  
24 slotted liners, wire wrapped and pre-packed screens,  
25 excluder, equalising and conslot screens and special  
26 strata pack membrane screens. These screens  
27 characteristically have symmetric, fixed geometry  
28 slots. However, when these screens are used in  
29 advanced wells, the screens are subjected to a non-  
30 uniform particulate plugging profile which results  
31 in "hotspots" developing in the screen; this is a  
32 major concern because it causes erosion of the

1 screen resulting in massive sand production.  
2 Follow-up workover operations of such screens are  
3 limited to in situ acid washes or vibration or  
4 insertion of a secondary slim screen (such as  
5 stratacoil) into the damaged screen, which has an  
6 adverse affect on reservoir inflow and well  
7 performance. Also, retrieval of damaged screens  
8 from specially extended-reach wells is almost  
9 impossible. Consequently, in adverse conditions,  
10 some wells have been abandoned and expensive side-  
11 tracks drilled.

12  
13 The main difference between the various screen  
14 systems currently in use resides in the geometry or  
15 configuration of the rigid screen shroud with its  
16 fixed, symmetric slots. These systems have  
17 different degrees of susceptibility to plugging and  
18 operations engineers are usually left with the  
19 problem of selecting the most appropriate screen  
20 systems to use for specific sand control completions  
21 from the range of screen systems currently  
22 available.

23  
24 Previous work by investigators has shown that the  
25 stability and bridging effectiveness of typical  
26 filtration media such as screen systems or  
27 gravelpacks are functions of operational,  
28 environmental and geometric parameters which are  
29 largely dependant on the following:

- 30 • Formation grain sized distribution and  
31 sorting;

- 1           •     Type of reservoir fluids and fluid
- 2                     properties;
- 3           •     Reservoir drawdown and production; and
- 4           •     The geometry of the filtration medium.
- 5

6     Thus for a defined operating and production rate and  
7     drawdown condition, a clastic unconsolidated  
8     reservoir will produce sand grains of a particular  
9     size distribution which is dependant on the  
10    reservoir characteristics. Thus the amount and size  
11    distribution of solids contained in a given barrel  
12    of fluid produced from an oil or gas well, depends  
13    on the bridging effectiveness of the filtration  
14    media used in the wells, wherein the bridging  
15    effectiveness can be evaluated for defined  
16    operational conditions.

17  
18    According to the invention there is provided a  
19    screen system for underground wells, the screen  
20    system comprising a screen;  
21    wherein the screen comprises a plurality of slots;  
22    and  
23    a mechanism capable of varying the size of the said  
24    slots.

25  
26    According to the invention there is provided a  
27    method of fluid flow control and/or sand production  
28    control in a well, the method comprising the steps  
29    of placing a screen having a plurality of slots in  
30    the well and varying the size of the slots.

31

1 Preferably, the screen system comprises a pair of  
2 screens comprising a slotted inner screen disposed  
3 within a slotted outer screen. Optionally, at least  
4 one screen shroud is further provided which is  
5 attachable to the outer screen.

6  
7 Typically, the inner screen is rotatable relative to  
8 the outer screen. Preferably, the inner screen  
9 comprises a substantially cylindrical member having  
10 a pair of ends wherein one end is rotatable relative  
11 to the other end by operation of the said mechanism.  
12 Typically, the mechanism comprises a motorised  
13 actuator.

14  
15 Preferably, the screen comprises a plurality of  
16 longitudinally arranged members and at least one  
17 transversely arranged member which combine to  
18 provide the slots in the interstices therebetween,  
19 wherein, rotation of one end of the screen causes an  
20 end of the longitudinally arranged members to rotate  
21 relative to the other end of the longitudinally  
22 arranged members such that the slot size is capable  
23 of being varied.

24  
25 Preferably at least one screen shroud is provided  
26 with electromechanical sensors.

27  
28 Preferably, the inner screen is rotated under the  
29 control of a controller which is further connected  
30 to the electromechanical sensors.

31



1 Preferably the controller employs a solids  
2 prediction model to calculate a control action.

3

4 Preferably the controller further employs a plugging  
5 tendency model to calculate a control action.

6

7 According to a second aspect of the invention, the  
8 screen system is further provided with an external  
9 screen shroud.

10

11 Preferably, the external screen shroud is  
12 perforated.

13

14 Embodiments of the present invention will be  
15 described by way of example only, with reference to  
16 the accompanying drawings, in which;

17 Figure 1a is a side elevation of a bottom  
18 section of the screen system, in accordance  
19 with the present invention, highlighting a  
20 protective shroud, an inner screen and base of  
21 the screen, without showing an outer screen;  
22 Figure 1b is a side elevation of an upper  
23 section of the screen of Figure 1a,  
24 highlighting the outer and inner screen without  
25 showing the protective shroud;

26 Figure 2 is a block diagram of an architecture  
27 for a system for controlling the slot angle of  
28 the screen system of Figures 1a and 1b; and  
29 Figure 3 is a flow chart showing the different  
30 stages in the process of controlling the slot  
31 angle of the screen system of Figures 1a and  
32 1b.

1 Referring to Figure 1a, a screen system 5 is shown  
2 for use in underground wells such as oil and gas  
3 wells (not shown), and is provided with an optional  
4 external protective shroud 10 substantially  
5 comprised of a high grade steel perforated pipe.  
6 The external protective shroud 10 acts as a blast  
7 protector and helps support any unconsolidated  
8 reservoir sand collapse around the screen system 5.  
9 The external protective shroud 10 is provided with a  
10 high density of perforations of large diameter, this  
11 feature minimises the development of any potential  
12 hotspots in the screen and provides a maximum area  
13 for fluids to flow through.

14  
15 In a second embodiment of the invention, the screen  
16 system 5 does not require an outer protective shroud  
17 10 and is used with a drill-in Liner (DIL) pre-  
18 installed within the well.

19  
20 Referring to Figure 1b, the shroud 10 (not shown in  
21 Figure 1b) encases two concentric slotted screens 12  
22 and 14, namely a rigid outer screen 12 and an inner  
23 screen 14 wherein the inner screen 14 is  
24 telescopically moveable relative to the outer screen  
25 12.

26  
27 A first end 16, in use upper end 16, of the outer  
28 screen 12 is provided with an aperture (not shown)  
29 through which a quick connect joint 18 extends. The  
30 quick connect joint 18 is sufficiently wide to fill  
31 the aperture.

32

1 A first end 19 of the inner screen 14 is provided  
2 with a rigid drive shaft 20 which is latchable onto  
3 a first end (not shown), in use lower end, of the  
4 quick connect joint 18. A second end 22 of the  
5 quick connect joint 18 is connectable to a hydraulic  
6 motordrive shaft (not shown) or electrohydraulic or  
7 electromagnetic actuator via a second quick connect  
8 joint to actuate or turn the upper end 19 of the  
9 inner screen 14 to a specified angle.

10

11 The quick connect joints at each end of the outer  
12 screen 12 have bearings that permit rotation of the  
13 inner screen 14. The inner screen 14 is driven by  
14 means of the drive shaft 20 at the upper end of the  
15 outer screen 12, which is urged by the  
16 electromagnetic/electrohydraulic actuator.

17

18 A swivel base 24 is welded to a second end (not  
19 shown), in use lower end, of the inner screen 14. A  
20 first end 26, in use upper end 26, of the base  
21 swivel 24 is attachable eg via a latch (not shown)  
22 to a second end 28, in use lower end 28, of the  
23 outer screen 12 to allow for minimal torque rotation  
24 of the inner screen 14. The first end 26 of the  
25 base swivel 24 and thus the lower end 28 of the  
26 inner screen 14 will normally remain stationary  
27 since the base swivel 24 has relatively high  
28 internal friction, but the minimum torque rotation  
29 feature has the advantage that the first end 26 and  
30 thus the lower end 28 of the inner screen 14 can  
31 rotate if the electrohydraulic actuator becomes  
32 stuck because, for example, sand is causing the

1 upper end 19 of the inner screen 14 to stick. This  
2 feature prevents the electrohydraulic or  
3 electromagnetic actuator from burning out.

4  
5 Alternatively the overtorquing can be restrained by  
6 frictionless bearings and the swivel, thereby  
7 preventing the motor from burning out.

8  
9 Returning to Figure 1a, the outer screen (not shown)  
10 and the inner screen 14 are provided with an  
11 interwoven lattice of outer screen shroud (not  
12 shown) and inner screen shrouds 30 respectively.  
13 Each shroud comprises a series of longitudinally  
14 arranged bands of material, such as steel of  
15 different grades selected in accordance with the  
16 well conditions. The bands are coated with micro-  
17 electromechanical system sensors (not shown) wherein  
18 each sensor is electronically linked to a control  
19 system (not shown). The respective lattice of outer  
20 screen shroud (not shown) and inner screen shrouds  
21 30 comprise a series of longitudinally arranged  
22 bands of material 301 which are spaced apart around  
23 the circumference of the respective outer 12 and  
24 inner 14 screens and extend parallel to the  
25 longitudinal axis of the screen system 5.  
26 Additionally, the respective lattice of outer screen  
27 shroud (not shown) and inner screen shrouds 30  
28 comprise a series of transversely arranged rings of  
29 material 30t which are spaced apart along the  
30 longitudinal axis of the screen system 5 and which  
31 are arranged to lie on planes perpendicular to the  
32 longitudinal axis of the screen system 5.

1 Accordingly, there are a plurality of slots 32  
2 provided in the interstices between the  
3 longitudinally arranged bands of material 30l  
4 transversely arranged rings of material 30t, where  
5 the size of the slots 32 of the inner screen 14 can  
6 be varied whilst the screen system 5 is in situ in  
7 the well, as will be described subsequently.

8  
9 Accordingly, operation of the electrohydraulic  
10 actuator rotates the upper end 19 of the inner  
11 screen 14 relative to the lower end 28 of the inner  
12 screen 14, which results in variation of the size of  
13 the plurality of slots 32 of the inner screen 14.

14  
15 Figure 2 is a block diagram of the architecture of a  
16 system for controlling the screen system 5. The  
17 micro-electromechanical system sensors of the screen  
18 system 5 are electronically linked to a measurement  
19 system 40 which is in turn connectable to a  
20 monitoring system 42 and an adaptive controller 44.  
21 The adaptive controller 44 is also provided with  
22 input data 46 relating to a desired value of a  
23 measurable variable of the screen system 5. The  
24 adaptive controller 44 is further connected to the  
25 screen system 5 and the monitoring system 42.  
26  
27 Figure 3 is a flow chart of the processes occurring  
28 within the screen system 5 and control system. In a  
29 first step 50 well data, production data, reservoir  
30 data, screen sensor data and default data are  
31 entered into a computer. The well data comprises

1 details of :

- 2 (I) the geometrical configuration of the well,
- 3 (ii) the type of completion of the well,
- 4 (iii) the designed screen O.D. and
- 5 (iv) gravelpack details if the well employs
- 6 gravelpack completions.

7

8 The production data comprises details of the  
9 production rate and flowing bottom hole pressure.

10 The reservoir data comprises details of the  
11 reservoir pressure, porosity, permeability and sand  
12 grain size distribution. The screen sensor data  
13 comprises details of the fluid flow velocity across  
14 the screen system, the pressure drop across the  
15 screen system and solids concentration across the  
16 screen system. The default data comprises the  
17 default screen pressure drop and the default maximum  
18 tolerance level for solids production.

19

20 In second step 52 the outer screen slot is pre-set  
21 to a standard gauge based on Saucier rule for the  
22 particular reservoir sand size distribution. In  
23 other words, the outer screen shroud lattice is pre-  
24 set prior to introduction of the screen system into  
25 the well such that the slots or gaps 32 provided  
26 between the longitudinally arranged bands of  
27 material 301 and transversely arranged rings of  
28 material 30t are set to the required size. In a  
29 third step 54 an optimum slot size 32 is computed  
30 for a given production rate and solids level. In a  
31 fifth step 56 the electrohydraulic actuator is  
32 instructed by the control system to rotate the inner

---

1 screen 14 to a desired angle in order to increase or  
2 decrease the area of the slots or gaps 32 in the  
3 inner screen 14 through which the fluid from the  
4 well can flow. In a sixth step 58 the flow through  
5 the screen system 5 and the solids loading on the  
6 screen system 5 are continuously monitored by the  
7 micro-electromechanical sensors and in a further  
8 step 60 compared with the default maximum tolerance  
9 level for solids production and the default plugging  
10 pressure drop across the screen system 5 which have  
11 been computed in accordance with the built in  
12 classic models and entered into the computer in  
13 stage 50.

14  
15 Any difference between the measured variables and  
16 the default values of the variables is communicated  
17 to the adaptive controller which in a further step  
18 62, accordingly activates the electrohydraulic  
19 actuator to operate the screen system 5 to minimise  
20 the difference between the measured data and the  
21 default data. Thus, the electrohydraulic actuator  
22 operates the screen system 5 to adjust the slot or  
23 gap size 32 of the inner screen 14 in accordance  
24 with the output of the adaptive controller, wherein  
25 rotation in one direction, for example a clockwise  
26 direction, of the upper end 19 relative to the lower  
27 end 28 reduces the slot size 32 such that the area  
28 through which the production fluids can flow is  
29 reduced which will reduce the production fluid flow  
30 rate. Conversely, rotation of the upper end 19  
31 relative to the lower end 28 in the other direction,  
32 for example a counter-clockwise direction, increases

1 the slot size 32 of the inner screen 14 such that  
2 the area through which the production fluids can  
3 flow is increased which will increase the production  
4 fluid flow rate.

5  
6 The adaptive controller calculates an appropriate  
7 control action by way of a solids production  
8 prediction model and a plugging tendency model. The  
9 solids production prediction model is based upon the  
10 principal that the degree of solids production or  
11 migration through a downhole solids control system  
12 depends upon the bridging effectiveness of the  
13 control system whether the control system be  
14 gravelpack or barefoot screen.

15  
16 The degree of solids production or migration through  
17 a downhole solids control system is a function of a  
18 number of variables including:

- 19 1. The formation of grain size distribution, shape  
20 and density.
- 21 2. The type and properties of reservoir fluid.
- 22 3. The fluid production rate or injection rate
- 23 4. The overall well drawdown.
- 24 5. The accumulative production
- 25 6. The hole angle
- 26 7. The type of completion.

27  
28 Accordingly the solids production is computed from  
29 an established mechanistic prediction model.

30  
31 Using a set of equations the maximum and minimum  
32 grain size invading the screen system 5 can be

---



1 computed from a given bridging efficiency. The  
2 maximum and minimum grain size invading the screen  
3 system 5 can be employed with the solids production  
4 concentration in a modified Ergun equation for  
5 predicting the flow through the filtration system.  
6 The plugging tendency model accounts for the effect  
7 of time cumulative production and pore blocking  
8 mechanisms on the flow filtration system. In the  
9 plugging tendency model the plugging tendency is  
10 quantified as a function of the pressure drop across  
11 the screen system 5, wherein the pressure drop  
12 across the screen system 5 is calculated as the sum  
13 total of the pressure drop across the screen  
14 aperture 32 itself and the pressure drop across the  
15 solid filter cake on the screen system 5.

16  
17 The invention is not limited by the examples herein-  
18 before-described which may be varied in construction  
19 and detail. For example, an outer screen could be  
20 omitted, with just an inner screen operating to  
21 control the sand production -in this embodiment, the  
22 control system would be modified accordingly.

Figure 1a

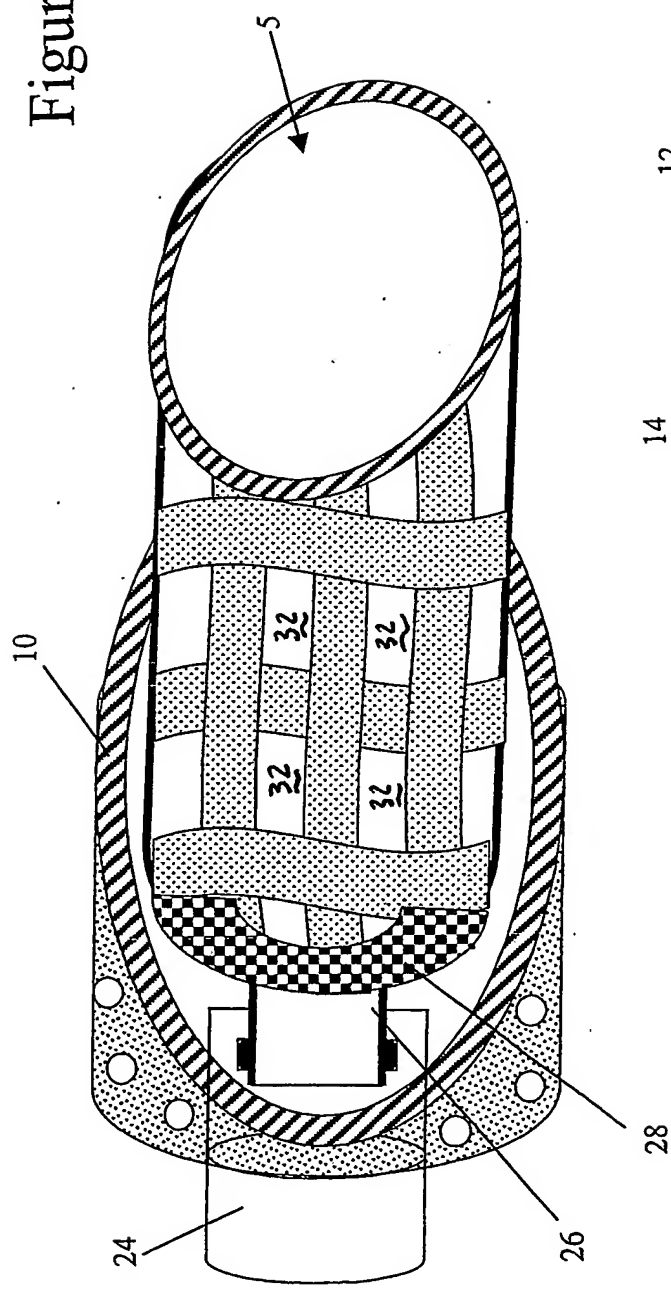
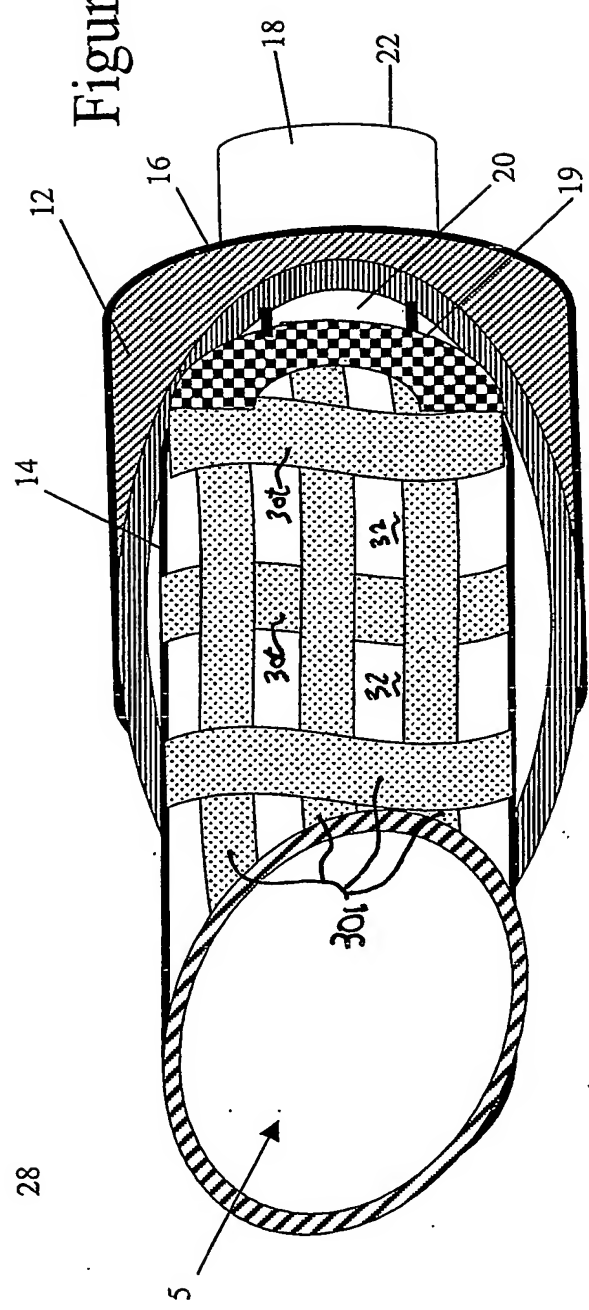


Figure 1b





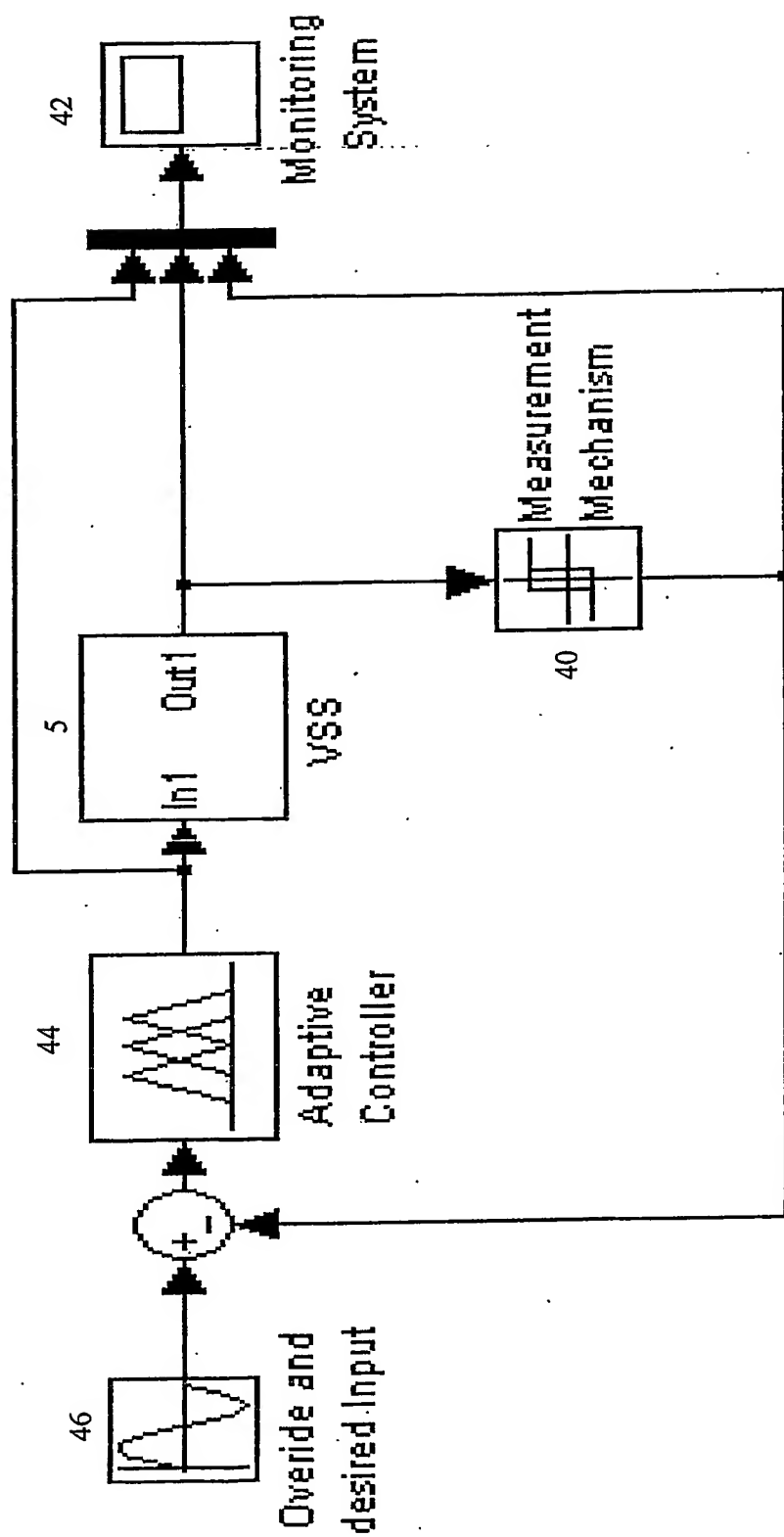


Figure 2



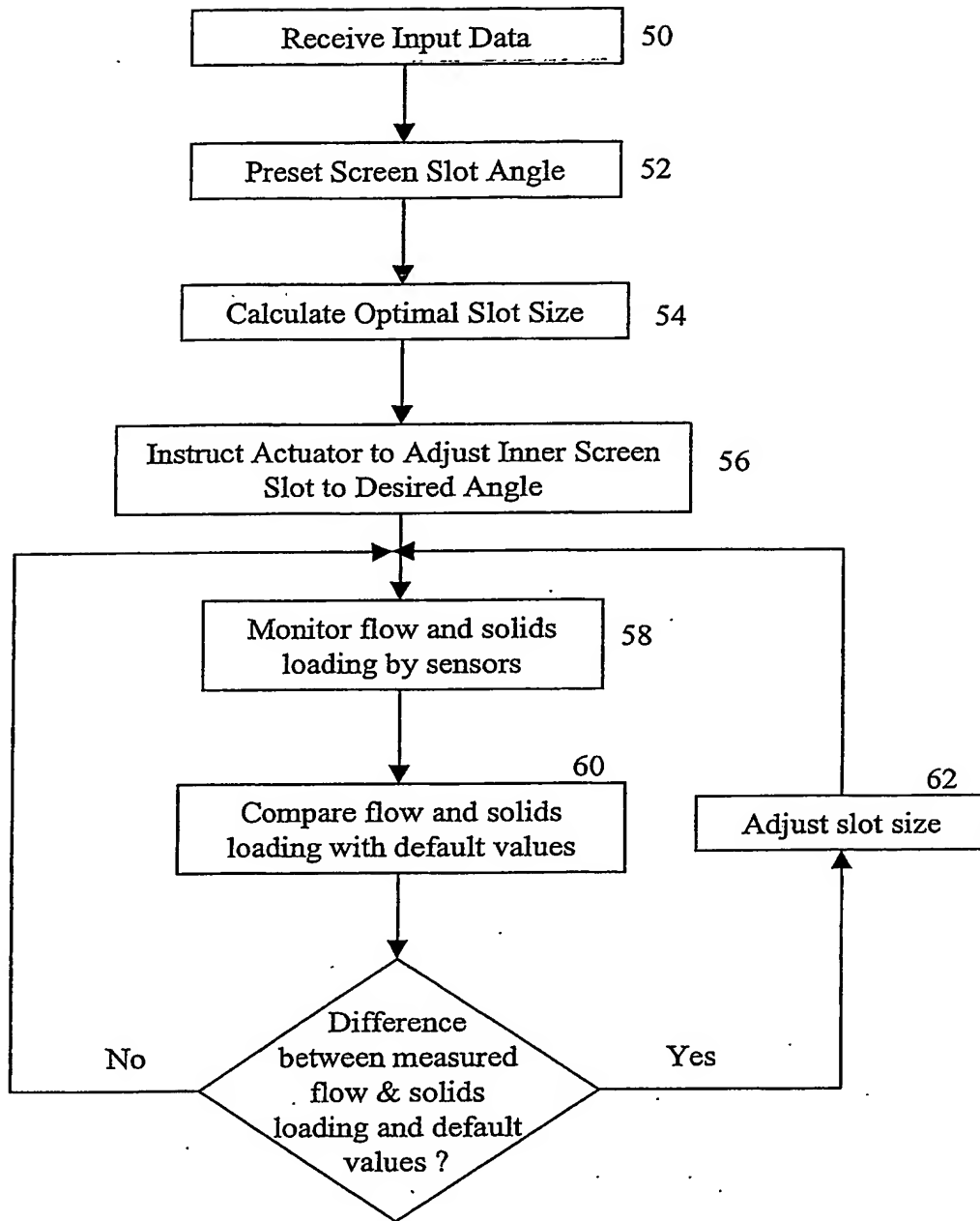


Figure 3

PCT Application  
**GB0303896**

